(12) UK Patent Application (19) GB (11) 2 366 938 (13) A

(43) Date of A Publication 20.03.2002

(21) Application No 0019110.6

(22) Date of Filing 03.08.2000

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(51) INT CL[7]
H04Q 7/38

(52) UK CL (Edition T)
H4L LRCMA L209

(56) Documents Cited

GB 2301740 A	GB 2278540 A
EP 1006244 A1	EP 0998073 A2
EP 0915630 A2	WO 99/39476 A1
WO 99/33299 A1	WO 98/00956 A2
WO 96/00485 A2	WO 00/72506 A1
US 5875394 A	US 5371784 A

(58) Field of Search
UK CL (Edition T) H4L LRCMA, H4P PDCSA
INT CL[7] H04L 9/32, H04Q 7/38
online: WPI, EDOC,JAPIO

(54) Abstract Title
Method of authentication in a mobile communication network

(57) A method of mutual authentication in a mobile communications network comprising authentication of a subscriber identifying means to a network entity and authentication of the network entity to the subscriber identifying means. The subscriber identifying means receives a challenge from the network entity and uses an algorithm and a stored input parameter to generate a response. The network entity adds a certificate to the challenge sent to the subscriber identification means.

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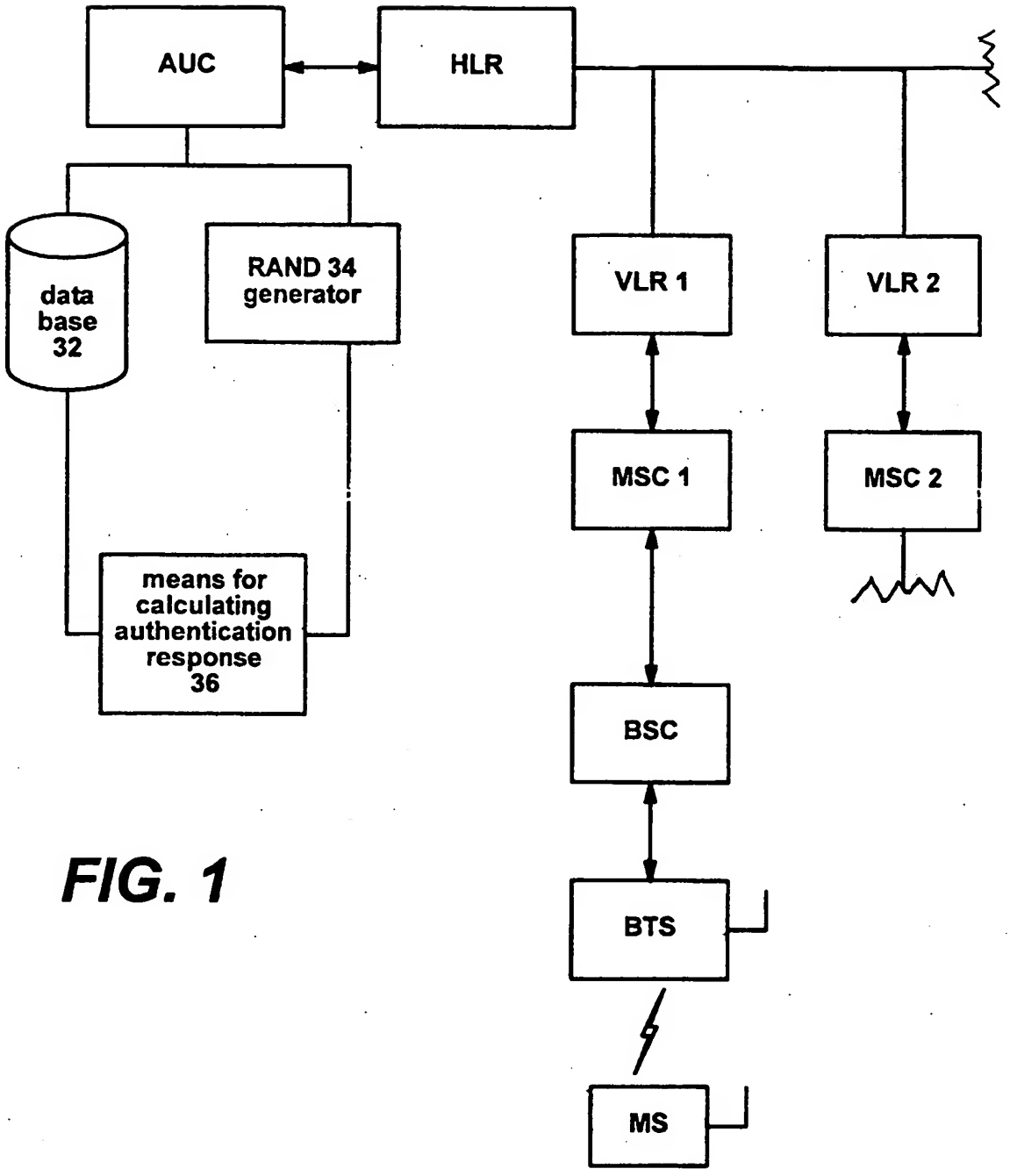

AUC
HLR
data base 32
RAND 34 generator
means for calculating authentication response 36
VLR 1
VLR 2
MSC 1
MSC 2
BSC
BTS
MS

FIG. 1

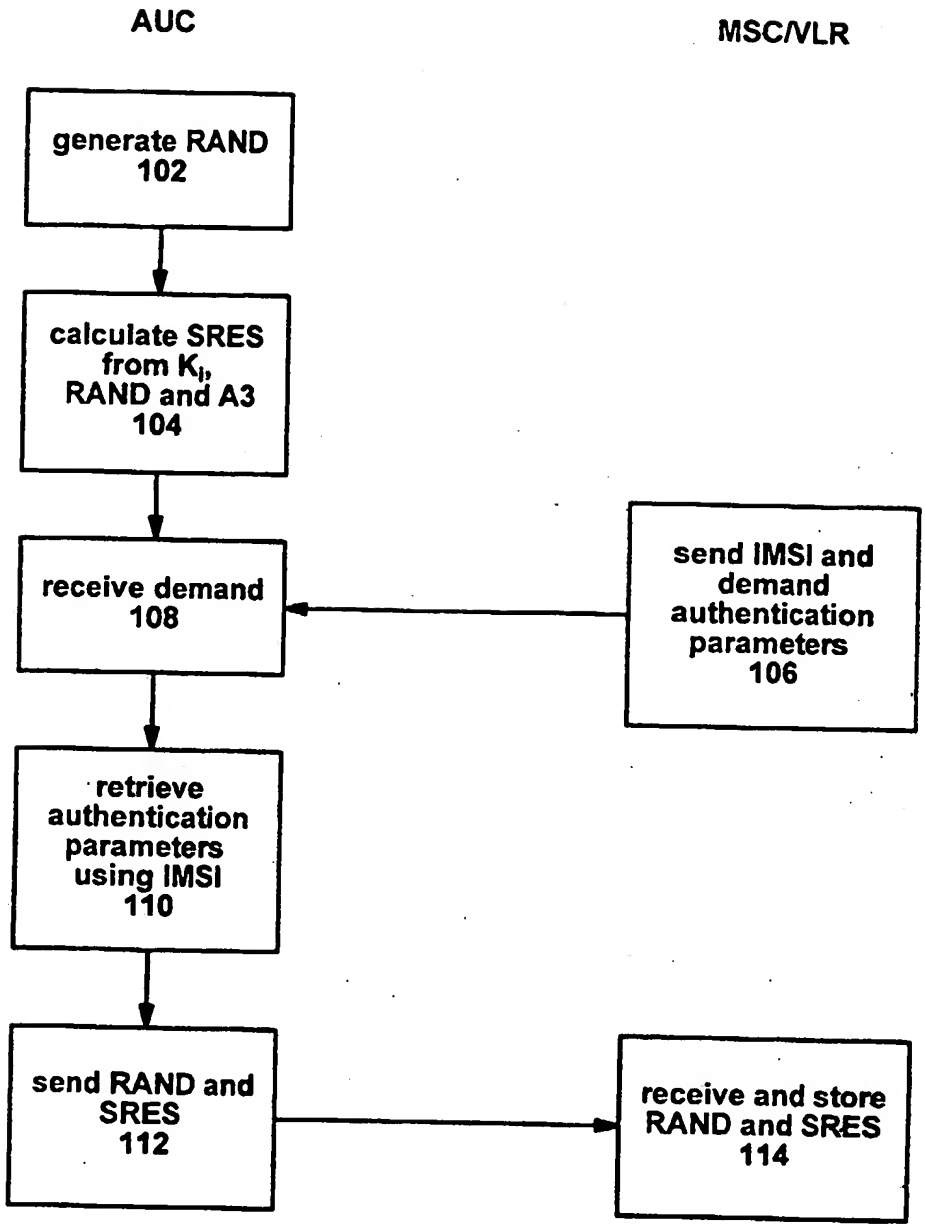


FIG. 2A
(PRIOR ART)

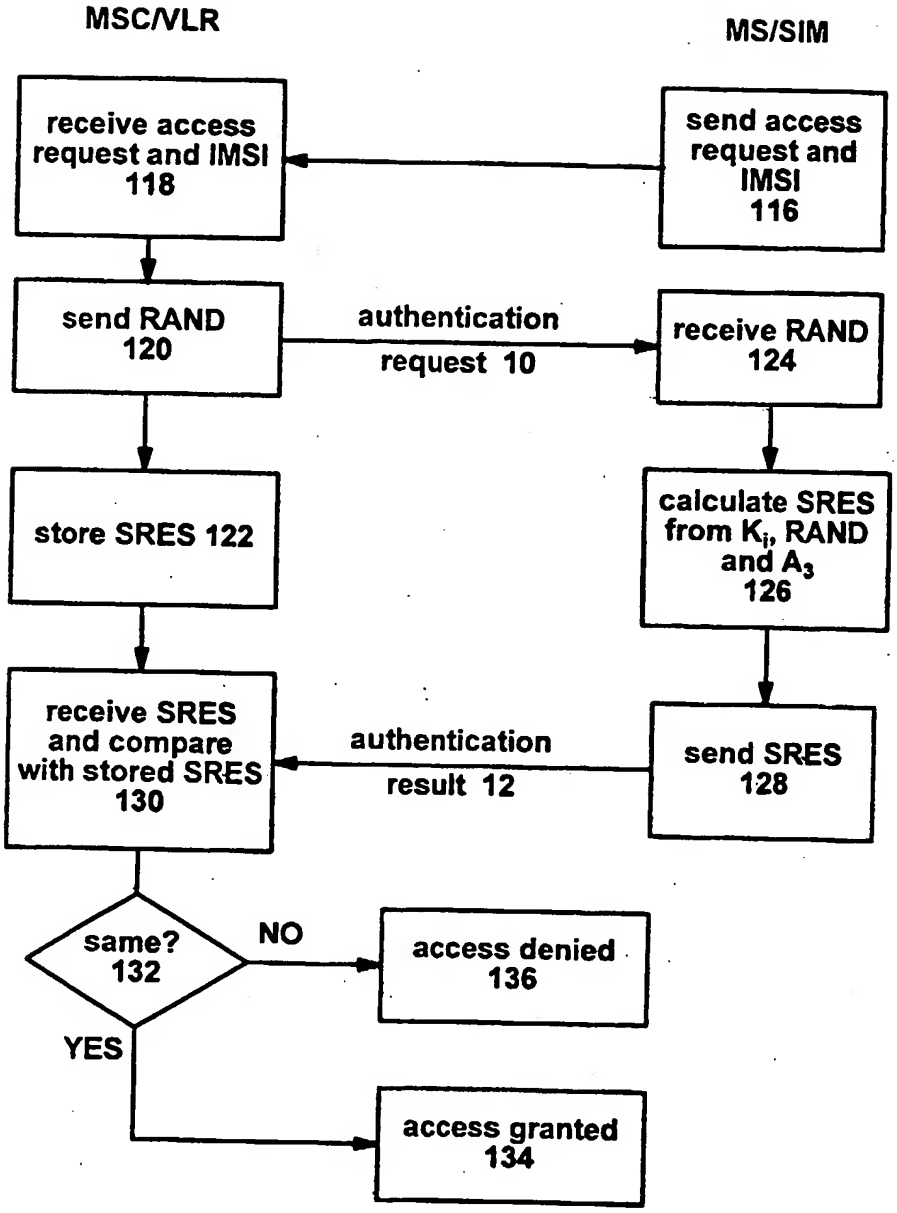


FIG. 2B
(PRIOR ART)

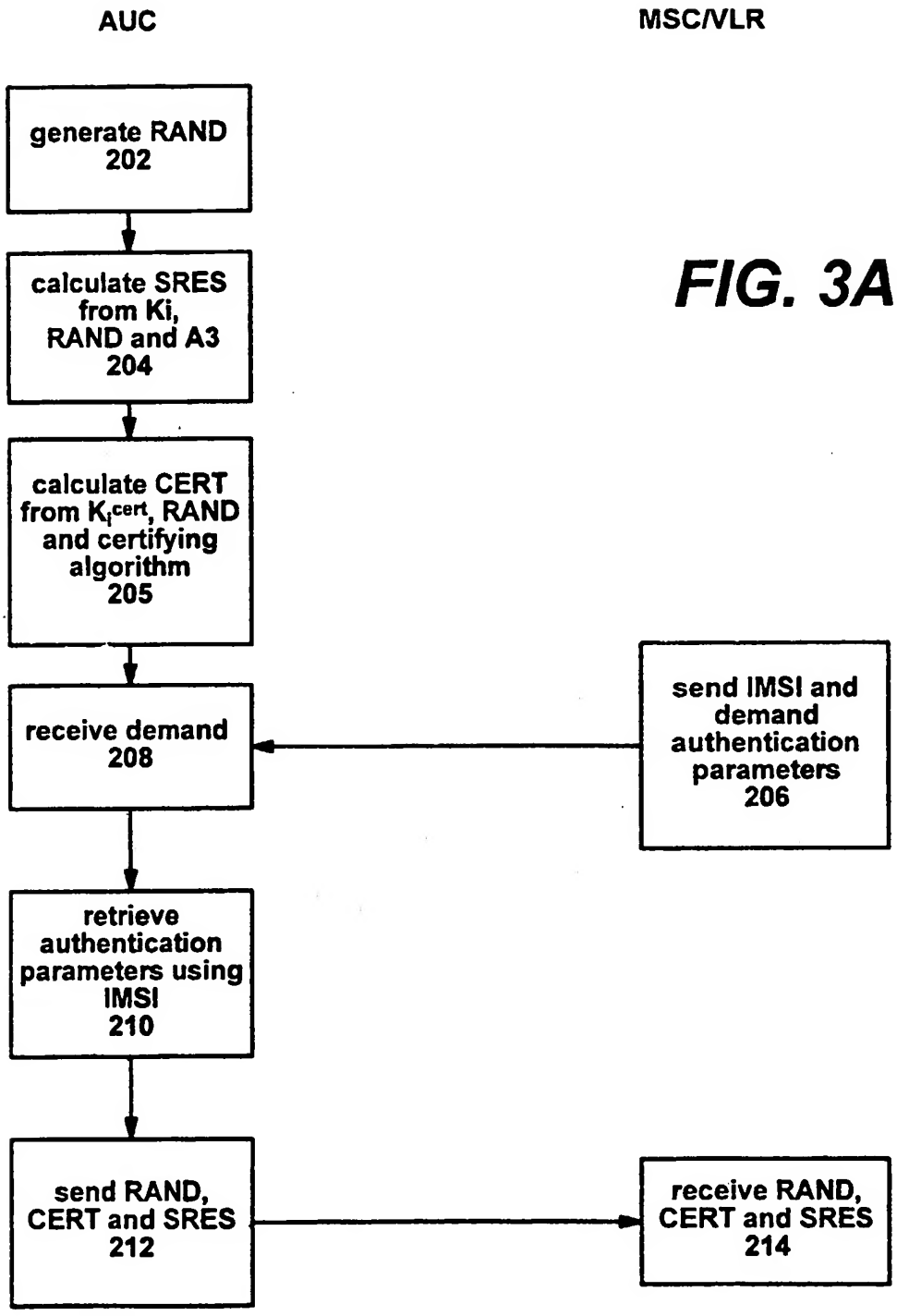

AUC
MSC/VLR
generate RAND 202
calculate SRES from Ki, RAND and A3 204
calculate CERT from K_i^{cert}, RAND and certifying algorithm 205
receive demand 208
send IMSI and demand authentication parameters 206
retrieve authentication parameters using IMSI 210
send RAND, CERT and SRES 212
receive RAND, CERT and SRES 214

FIG. 3A

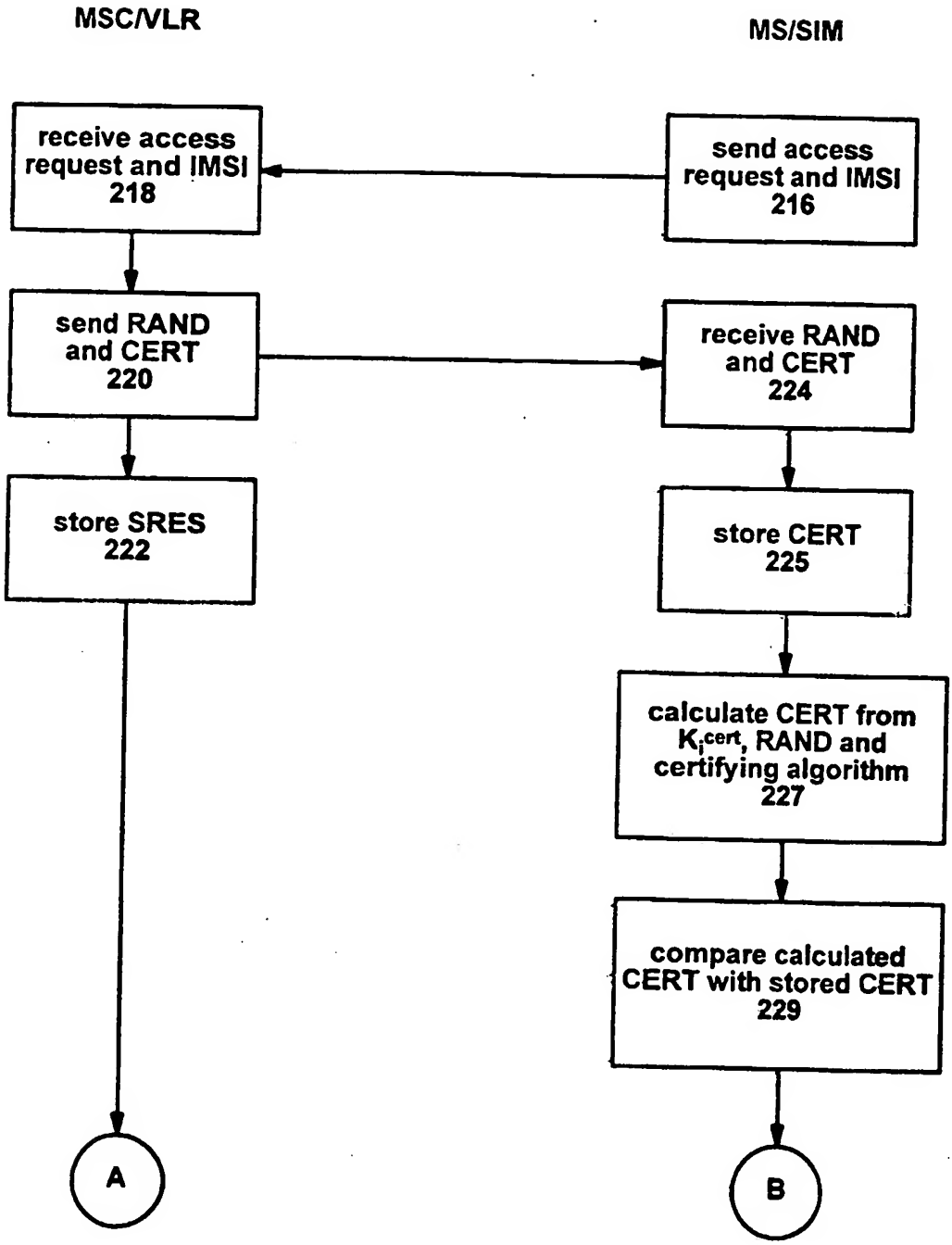

MSC/VLR
MS/SIM
receive access request and IMSI 218
send access request and IMSI 216
send RAND and CERT 220
receive RAND and CERT 224
store SRES 222
store CERT 225
calculate CERT from K_i^{cert}, RAND and certifying algorithm 227
compare calculated CERT with stored CERT 229
A
B

FIG. 3B

FIG. 3C

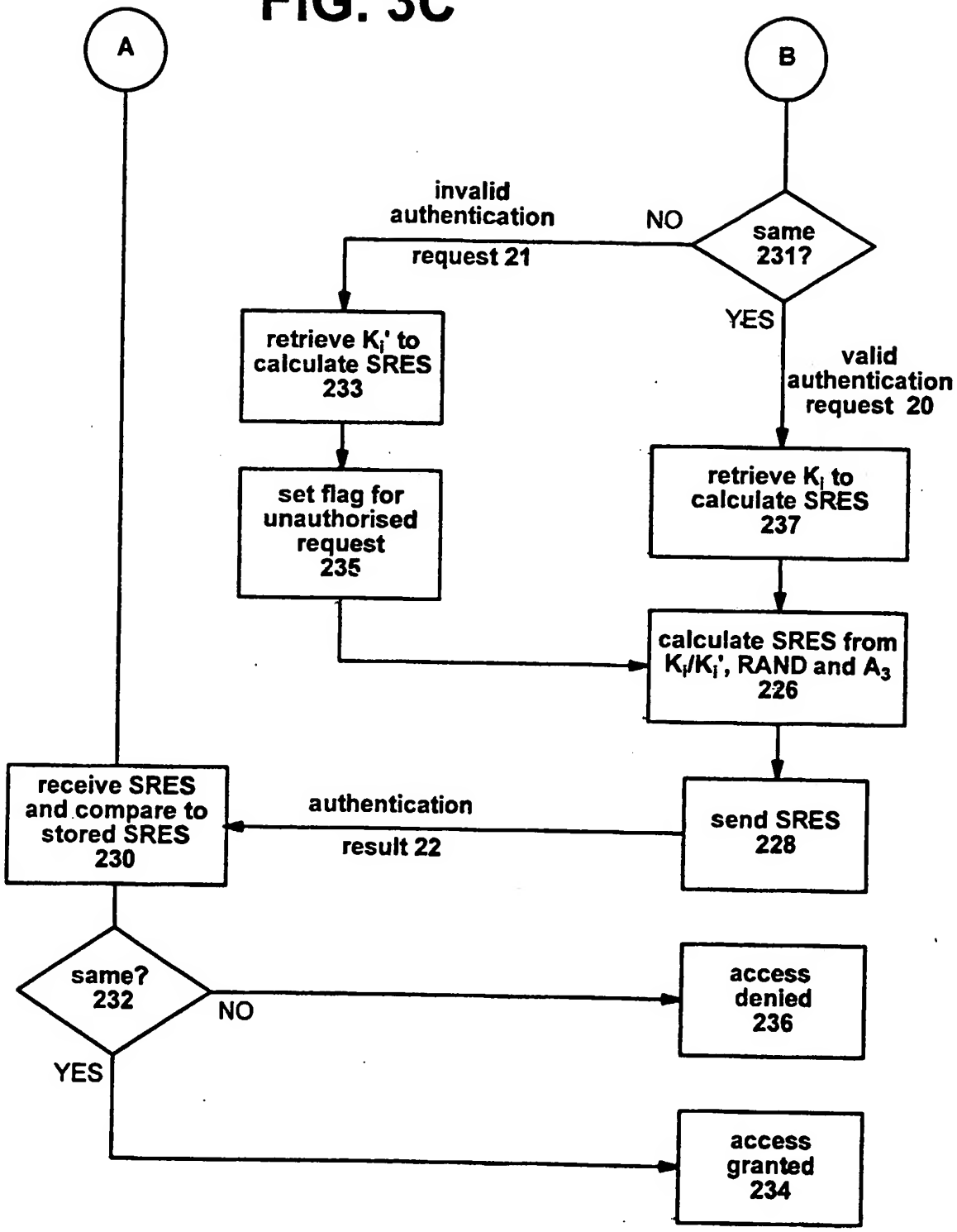

A
B
invalid authentication request 21
NO
same 231?
YES
valid authentication request 20
retrieve K_i' to calculate SRES 233
set flag for unauthorised request 235
retrieve K_i to calculate SRES 237
calculate SRES from K_i/K_i', RAND and A_3 226
receive SRES and compare to stored SRES 230
authentication result 22
send SRES 228
same? 232
NO
access denied 236
YES
access granted 234

FIG. 4

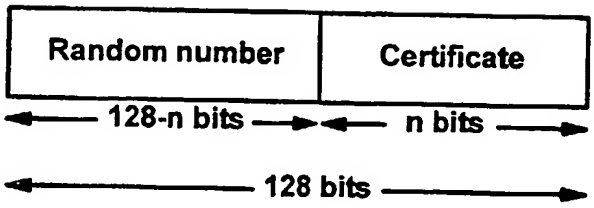


FIG. 6

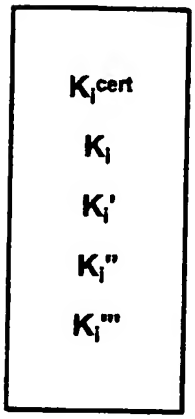


FIG. 5A
(PRIOR ART)

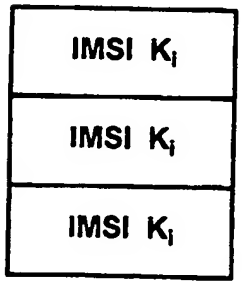


FIG. 5B

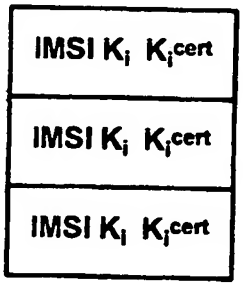
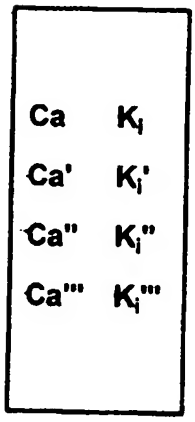


FIG. 7



Authentication in a Mobile Communications Network

This invention relates to a method of authentication, in particular, but not exclusively, in a mobile communications network.

In a known conventional GSM (Global System for Mobile Communications) system, each mobile station, such as a mobile telephone handset, is provided with a SIM, which is inserted into the mobile station in order to allow the mobile station to receive service in a GSM network.

A typical SIM includes a microprocessor, memory elements including a permanent memory (e.g. ROM), a non-volatile rewritable memory (e.g. EEPROM) and a volatile rewritable memory (e.g. RAM), and contacts for forming the data transfer interface between the SIM and the mobile station.

In the following it is referred to Fig. 1, 2A and 2B. The basic structure of a GSM system is shown in Fig. 1. The GSM standard also specifies the process of authenticating the user to the network. This process is illustrated in Fig. 2.

Referring now to Fig. 1, there is a home location register (HLR) storing information of all the subscribers to a network. The subscriber data contain information of the services to which the subscriber may have access and the current location of the subscriber. Connected to the HLR are a number of visitor location registers VLR1, VLR2, etc. Each VLR is attached to or integrated in a mobile switching centre MSC. The MSC is connected to

a base station controller (BSC). The BSC serves a number of cells, each having a transceiver station (BTS). The BTS communicates with a mobile station (MS) via radio connections. An authentication centre AuC is connected to the HLR. The AuC handles the authentication of the subscriber to the network as will be explained in the following.

Referring now to Fig. 2A and Fig. 1, the visited Mobile Service Switching Centre (MSC)/Visitors Location Register (VLR) sends parameters including the International Mobile Subscriber Identity (IMSI) to the Authentication Centre (AuC) and demands authentication parameters (step 106). The authentication centre is linked to a Home Location Register (HLR) of the subscriber. When a subscription is started, a secret number called an authentication key (K_i) is allocated to the mobile subscriber together with the IMSI. The AuC comprises a database 32 which stores the authentication key K_i for each mobile subscriber in the GSM network as is illustrated in Fig. 5A. The key K_i is unique to the subscriber. It is shared only by the subscriber's SIM card and the authentication centre which serves the subscriber's home network. The key K_i is stored on the SIM in a very protected way: it is not possible to retrieve the key K_i from the SIM. The K_i of the mobile subscriber can be retrieved from database 32 using the IMSI of the subscriber as an index. The AuC is further provided with means for calculating authentication responses 36 including an authentication algorithm A_3. The GSM system further specifies the size of the random input parameter RAND (128 bits) and

of the output parameter SRES (32 bits). K_i may have any format and length. The authentication algorithm A_3 is provided by the network operator and kept secret. A random generator 34 provides random numbers RAND having length of 128 bits (step 102). The key K_i retrieved from database 32 and the random number RAND are used as input parameters in the authentication algorithm A_3 to calculate the signed response SRES (step 104). Authentication algorithm A_3 is a so-called one-way hash function. This ensures that the computation of the authentication response SRES (signed response) from the key K_i and the random number RAND is easy, whereas the computation of the key K_i knowing RAND and the authentication response SRES is as complex as possible. Even with the knowledge of several pairs of authentication challenges and responses (RAND, SRES) pertaining to the same subscriber, the computation remain highly complex. At the same time a ciphering key K_c is calculated using authentication key K_i and random number RAND as input parameters in a ciphering algorithm A_8. The triplet comprising the random number RAND, the signed response SRES and the ciphering key K_c are sent from the AuC to the visited MSC/VLR in step 112. Such a triplet is used only once, i.e. for one communication and is then destroyed. Several triplets are calculated in advance for each subscriber at authentication centre AuC and are delivered to the MSC/VLR on request. Such a request contains the IMSI of subscriber and a demand for authentication parameters (step 106). The IMSI is used to retrieve parameters

pertaining to the subscriber (step 110), and a number of triplets are transmitted from the authentication centre AuC to the visited MSC/VLR (step 112). A reserve of a few of the triplets are stored in the MSC/VLR (step 114). Referring now to Fig. 2B, upon access request of a mobile station (MS) in step 116 and 118 a triplet is retrieved from storage in the MSC/VLR using the IMSI. The value of SRES is stored in the MSC/VLR in step 122. The random number RAND is further transmitted from the MSC/VLR to the Mobile Station MS as a request for authentication (10) of the subscriber to the network in step 120 and 124. The SIM stores a copy of the key K_i of the subscriber and the authentication algorithm A_3 for calculating the signed response SRES for verification.

The response SRES is accordingly calculated using K_i and RAND as an input for authentication algorithm A_3 (step 126) and the response is transmitted in step 128 to the MSC/VLR as an authentication result (12). The MSC/VLR then compares the signed response SRES transmitted from the AuC and already stored in the MSC/VLR with the signed response SRES transmitted from the mobile station as an authentication result 12 in steps 130 and 132. If the two values for SRES are identical, access of the subscriber to the network is granted by the MSC/VLR in step 134. If the two values are not identical, access is denied in step 136.

However, the system described above is open to various attacks to gain access to the secret key K_i. By repeatingly sending random numbers

RAND as authentication challenges to the SIM and by monitoring the signed responses SRES the SIM will provide, it might be possible to derive the value of the secret key K_i and possibly also the authentication algorithm A_3. This is called a multiple attack. Although the use of a one-way hash function for A_3 ensures a considerable level of complexity of the computation, the secret key K_i may be discovered with a finite number of attacks. With the knowledge of both the secret K_i and the authentication algorithm A_3 one or more clone SIM cards may be generated.

It is an object of the present invention to provide a better, more secure, mechanism for authenticating the subscriber to the network. It is a further object of the present invention to nullify potential multiple attacks and the attempts to derive the value of the secret authentication key K_i and thus to prevent or further reduce the production of clone SIM cards.

According to one aspect of the present invention, there is provided a method of authentication in a mobile communications network comprising authentication of the subscriber identifying means to a network entity and authentication of the network entity to the subscriber identifying means.

In this way mutual authentication is achieved and unauthorised attempts to request authentication responses of the subscriber identifying means or SIM card, for example in multiple attacks, are prevented.

Preferably, the mutual authentication is achieved by authorising the authentication challenge from the network entity with a certificate, thus

authenticating the network entity to the subscriber identifying means. In this way authorised requests from the MSC/VLR can be distinguished from unauthorised requests from a potential attacker.

Preferably, the true authentication response to said authentication challenge is only given to a request carrying a valid certificate. Thus a disclosure of the secret authentication key following multiple attacks may be prevented. Preferably, said certificate includes a digital signature, a message authentication code (MAC) or a redundancy check code.

Preferably the procedure of responding to said authentication challenge is the same for a valid and an invalid certificate and a first input parameter or algorithm is used for said procedure of responding to a valid certificate and at least one further input parameter or algorithm, different from said first input parameter or algorithm, is used for said procedure of responding to an invalid certificate.

Thus the same procedure is applied to respond to valid and invalid authentication challenges. Even if the multiple attacks of the SIM are performed with help of a card reader no differences in the procedure to response to valid and invalid request could be detected. In this way a potential attacker would not be alerted that the attack is being nullified. This reduces further the chance for a potential attacker to discover the secret authentication key K_i.

Preferably, data are stored on said subscriber identifying means indicating that said subscriber identifying means has been subject to a request for authentication with an invalid certificate.

In this way the network may have access to the information that an attempt has been made to challenge the subscriber identifying means in an unauthorised way and precautionary steps may be undertaken to prevent or minor any further attempts.

According to another aspect of the present invention, there is provided a method of authentication in a mobile communications network using an information storage means, said method comprising the steps of: said information storage means receiving a message comprising an authentication challenge and determining a characteristic of said message; performing a first procedure if said message has a first predetermined characteristic; and performing a second procedure if said message has a different characteristic.

According to another aspect of the present invention, there is provided a method of authentication using an information storage means, said information storage means receiving a message comprising an authentication challenge and determining a characteristic of said message; said information storage means comprising means for calculating an authentication response based on said authentication challenge, an authentication input parameter and an authentication algorithm, said method comprising the steps of: retrieving one authentication input parameter from a number of input parameters stored

on said information storage means or one authentication algorithm from a number of algorithms stored on said information storage means in response to said characteristic; and responding to said authentication challenge by using said retrieved authentication input parameter or algorithm.

This provides an alternative way to prevent disclosure of the secret authentication key K_i and thus to prevent cloning of the SIM card.

Preferably, a sequence of messages comprising said authentication challenge and said certificate or authentication code has the appearance of randomness.

For authentication in a mobile communications network in accordance with the GSM standard, said authentication challenge preferably comprises a message of (128-n) bits and said certificate or authentication code comprises a message of n bits, such that a message comprising said authentication challenge and said certificate or authentication code is 128 bits long.

In this way a potential attacker may not recognise that the authentication challenges carries a certificate or authentication code. This helps further to nullify the attack because the message containing the authentication challenge RAND together with the certificate or authentication code has the same format and length than an authentication challenge according to the conventional GSM standard.

According to another aspect of the present invention, there is provided a method of authentication, comprising distinguishing an authorised request

for authentication from an unauthorised request for authentication and responding differently to authorised requests than to unauthorised requests.

In this way unauthorised attempts to request authentication can be distinguished from requests for authentication originating from the true authenticator and only in the latter case the true response to the authentication challenge is given.

According to another aspect of the present invention, there is provided a method of authentication, comprising the step of using a first valid input parameter or a first valid authentication algorithm to respond to an authorised authentication challenge and using a second input parameter or a second algorithm, different from said first input, to respond to an unauthorised authentication challenge.

In this way the same procedure is used for responding to a valid and invalid authentication challenge. Thus the mechanism prevents unauthorised attempts to request authentication of the SIM card in such a way as not to alert the potential attacker that the attack is being nullified.

According to another aspect of the present invention, there is provided an authentication centre for a mobile communications network, comprising:

a database storing a secret authentication input parameter for subscribers of said mobile communications network;

a source for providing random numbers as second input parameters;

means for calculating certificates for authorising authentication challenges, including an algorithm for calculating said certificates; and

means for calculating authentication responses, including an algorithm for calculating said responses.

According to another aspect of the present invention, there is provided an authentication centre for a mobile communications network, comprising:

a database storing:

i) an authentication algorithm and at least two secret first input parameters; or

ii) a secret first input parameter and at least two different authentication algorithms for calculating authentication responses;

a source for providing second input parameters for calculating said authentication responses;

means for:

i) determining characteristics of said second input parameters; or

ii) providing authentication codes;

means for assigning one of said at least two secret first input parameters or authentication algorithms to said characteristics or said authentication codes in a predetermined way;

means for retrieving the assigned first input parameter or authentication algorithm from said database; and

means for calculating said authentication responses using said assigned first input parameter or authentication algorithm.

In this way the known mechanisms for authentication only require minor modifications to achieve mutual authentication according to one aspect of the present invention. The same principal and components in an extended form are used, such as in the well-known GSM authentication process.

According to another aspect of the present invention, there is provided an information storage means for authentication, adapted for distinguishing authorised and unauthorised requests for authentication and for responding differently to said authorised and said unauthorised authentication requests.

By responding differently to authorised and unauthorised authentication challenges the chance for discovering the secret authentication input parameter or key K_i in an multiple attack are substantially reduced.

Preferably said authentication requests comprising authentication challenges carry certificates for authorising said authentication challenges and the validity of said certificates can be checked by calculation of said certificates from a certifying key and certifying algorithm stored on said information storage means using said authentication challenges as input parameters and comparison of calculated and received certificates.

In this way the same procedures and methods are used for authorising said authentication challenge itself. Only minor modifications have to be

applied to the subscriber identifying means and known technology may be used.

Preferably said information storage means adapted for storing a first authentication input parameter or algorithm for use in a procedure of responding to authorised requests for authentication and further adapted for storing at least another authentication input parameter or algorithm for use in a procedure of responding to unauthorised requests.

In this way the same procedure is used for calculating the response to a valid and an invalid authentication challenge and therefore no possibility for a potential attacker is provided to distinguish an authentication challenge with valid certificate from one with an invalid certificate.

According to another aspect of the present invention, there is provided an information storage means for authentication, comprising:

means for calculating authentication responses to received authentication challenges using said challenges, an authentication input parameter and an authentication algorithm stored on said information storage means;

means for:

i) determining characteristics of said authentication challenges; or

ii) determining characteristics of received authentication codes;

means for storing:

i) an authentication algorithm, at least two secret authentication input parameters; or

ii) a secret authentication input parameters, at least two authentication algorithms

means for determining predetermined assignments of said characteristics to said at least two authentication input parameters or algorithms; and

means for retrieving the assigned authentication input parameters or algorithms for a particular characteristic or authentication code and using said assigned authentication input parameter or algorithm for calculating said authentication responses.

In this way the possibility of the detection of the secret authentication key or keys is reduced.

Preferably in a mobile communications network according to the GSM standard, a received message comprising said authentication challenge and said certificate or authentication code has the same appearance as an authentication challenge according to the GSM standard.

In this way a potential attacker may not distinguish an authorised authentication challenge according to this aspect of the present invention from an authentication challenge according to the conventional GSM standard and the potential attacker would not be alerted that the attack is nullified.

According to another aspect of the present invention, there is provided a subscriber identifying means for authentication in a mobile communications network, adapted for distinguishing a genuine authentication challenge as transmitted by said network from a false authentication challenge and for storing data indicating that said subscriber identifying means has been subject to false authentication challenges.

In this way a false authentication challenge by a potential attacker is detected and the network may be notified of the false attack and actions to prevent further attacks or misuse may be started.

According to yet another aspect of the present invention, there is provided a method of authentication in a mobile communications network, comprising transmitting an authentication request to a mobile station and receiving an authentication response from the mobile station, wherein the authentication request transmitted to the mobile station comprises:

an authentication challenge; and

a certificate, said certificate providing authentication of a network entity to or an authentication code for determining a procedure for responding to said authentication challenge.

According to a further aspect of the invention there is provided a method of authentication in a mobile communications network,

wherein a network entity transmits an authentication challenge to a subscriber identifying means and generates an authentication response to said challenge,

wherein said subscriber identifying means generates an authentication response to said received challenge and transmitting said response to said network entity,

wherein said network entity compares the authentication response generated by said network entity to the authentication response provided by said subscriber identifying means, and

wherein said method comprises the steps of generating said authentication responses using a variable external input parameter available to said network entity and said subscriber identifying means and calculating said authentication response in response thereto.

Further aspects and advantages of the invention will be apparent from the following, in which one embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a general outline of the structure of a mobile communications network;

Figure 2A is a flowchart diagram showing the steps between the authentication centre AuC and the visited MSC/VLR in the authentication procedure according to the GSM standard (prior art);

Figure 2B is a flowchart diagram showing the steps between the visited MSC/VLR and the mobile station including the SIM card in the authentication procedure according to the GSM standard (prior art);

Figure 3A is a flowchart diagram showing the steps between the authentication centre AuC and the visited MSC/VLR in the mutual authentication procedure according to one embodiment of the present invention;

Figures 3B and 3C are flowchart diagrams showing the steps between the authentication centre AuC and, the mobile station including the SIM card in the mutual authentication procedure according to one embodiment of the present invention;

Figure 4 is an outline of the random number RAND and the certificate according to one embodiment of the present invention;

Figure 5A shows the database content for retrieving the authentication key in the authentication centre AuC (prior art);

Figure 5B shows the database content for retrieving the authentication key and the certifying key in the authentication centre AuC according to one embodiment of the present invention;

Figure 6 shows the storing of the certifying key and of different authentication keys in the SIM for use to response to authorised and unauthorised authentication challenges according to one embodiment of the present invention;

Figure 7 shows the storing of authentication codes and of authentication keys and their assignment in the SIM for use to respond to authentication requests comprising an authentication challenge and an authentication code according to a second embodiment of the present invention.

Figures 3A, B and C show the procedure of mutual authentication according to one embodiment of the present invention. Referring now to Fig. 3A, the steps of sending a demand of authentication parameters and the IMSI from the MSC/VLR to the authentication centre AuC (step 206) and step 202 and 204 of generating RAND and calculating authentication response are similar as steps 102, 104, 106 shown in Figure 2A and described above. However, the random number RAND used in this embodiment of the present invention is shorter than 128 bits. At subscription time, a second secret number called a certifying key K_i^{cert} is allocated to the subscriber, together with the IMSI and the authentication key K_i. The certificate key K_i^{cert} is stored in database 32 and can be retrieved together with K_i with IMSI as an index. Authentication algorithm A_3 is used to calculate SRES from RAND and K_i in step 204. A certifying algorithm is used to calculate a certificate CERT from RAND and K_i^{cert} in step 205. RAND, CERT and SRES are transmitted from authentication centre AuC to MSC/VLR on demand in step 212 and 214. Referring now to Fig. 3B, upon access request from mobile station MS (step 116), SRES is stored in step 222 in the visited MSC/VLR

and RAND is transmitted together with certificate CERT in one message from the MSC/VLR to the mobile station in step 220 and 224.

In contrast to the prior art and common GSM authentication procedure, where a 128 bit random number RAND is used, the random number RAND according to the described embodiment of the present invention is n bits shorter than 128 bits. n bits are reserved for the certificate CERT. The certifying algorithm, the certificate key K_i^{cert} and the random number RAND are chosen to match these requirements. As a result the authentication request comprising the authentication challenge RAND the certificate CERT is 128 bits long. In this way the sequence of messages comprising RAND and CERT as transmitted from MSC/VLR to the mobile station MS would have the appearance of randomness and could not be distinguished from prior art 128 bit random number RAND by an unauthorised attacker. A set of random number RAND and certificate CERT is illustrated in Fig. 4 as an example. However, it is appreciated that the certificate CERT may be located anywhere within the sequence of messages comprising RAND and CERT and is not restricted to a location at the end of the sequence. The certificate may for example be included in the sequence while being split into two or more portions, may be distributed in various manners, or may be coded in the random number RAND according to a predetermined procedure. The SIM connected to mobile station MS is provided with the same certifying algorithm and certificate key K_i^{cert} and is

thus able to check the message containing the random number RAND and certificate CERT for authentication. The SIM stores the transmitted CERT in step 225. In step 227 the SIM calculates CERT using the transmitted random number RAND and the key K_i^{cert} and certifying algorithm stored in the SIM memory. Subsequently, the stored and the calculate values of CERT are compared (step 229). Referring now to Fig. 3C, if the two values are identical, it is ensured that the authentication challenge is valid and assumed that it was provided by the MSC/VLR. In this case the SIM now continues to respond to the authentication challenge by calculating SRES from K_i and RAND in step 237 and 226 as explained before. If the two values of CERT are not identical, an invalid authentication challenge 21 is detected. In order to provide protection against multiple challenge attacks, it is not sufficient to provide an error message or no response from the SIM card if the two values of CERT are not identical, i.e. an invalid authentication challenge is detected. This would provide potential attackers with a hint that the challenges RAND are not truly random.

In case of an invalid authentication challenge, the SIM uses a second, fake authentication key K_i' to calculate a fake authentication response SRES 233 (step 233 and 226). This second key Ki' is also stored in the memory of the SIM. In both cases, i.e. a valid and invalid authentication challenge, the resulting SRES is transmitted to the MSC/VLR as the authentication result 22 in steps 228 and 230. The procedure of comparing the stored authentication

result SRES as received from authentication centre AuC with SRES received from the mobile station and granting or denying access in steps 232, 234 and 236 are the same as in steps 132, 134 and 136 of Fig. 2.

In case an invalid authentication challenge 21 is detected, a flag is set on the SIM indicating that an unauthorised authentication challenge has been detected (step 235).

As explained above, the SIM card returns an authentication response for every challenge, a valid and thus authorised authentication challenge 20 and also an invalid i.e., unauthorised, authentication challenge 21. To further enhance the security provided, it is important that the system performs the same procedure as a response for valid and invalid authentication challenges. In this way a potential attacker would not be able to detect any differences if the SIM card is measured in a card reader or the like. Thus, no hint is given to the potential attacker whether the authentication challenge is valid or not. Otherwise the potential attacker may discover the certifying key K_i^{cert} in a first series of multiple attacks and may continue challenging the SIM using the correct certificate in a second series of attacks in order to discover the authentication key K_i. According to the above-described embodiment of the present invention, however, no hint is given that the attempts are being nullified and that the responses to invalid authentication challenges are meaningless. This method enhances further the security of the authentication

system. A potential attacker may well derive the second authentication key K_i', but this is of no use in generating a clone SIM card.

Whilst in the above-described embodiment the method of authorising the authentication challenge is described as a certifying algorithm with a secret key K_i^{cert} as an input parameter, i.e. an authorisation according to the message authentication code (MAC) method, it is appreciated that other possibilities to authorise the authentication challenge like, for example, digital signature or redundancy check codes can be used. By adjusting the length of the keys K_i, K_i^{cert}, of the random number RAND and the certificate CERT it is even possible to use one of the existing GSM algorithms stored on the SIM, for example A_3, as a certifying algorithm. However, it is preferred that the length and appearance of a message containing the authentication challenge RAND and the certificate is the same as for an authentication challenge according to the prior art.

It is appreciated that even other possibilities for authorising the authentication challenge can be used: For example the random number RAND generated by the authentication centre AuC is provided with a predetermined code. Subsequently the message comprising RAND and the code is encrypted with a secret key. A sequence of these encrypted messages would again have the appearance of randomness and could be adjusted to have 128 bit length of prior art authentication challenges, in order not to give a hint to a potential attacker that the authentication challenges carry authorisation

certificates. The encrypted message is then transmitted via the visited MSC/VLR to the mobile station and its SIM. The SIM would be provided with the same secret key to decrypt the message. In this way the predetermined code can be checked by the SIM for authorisation of the random number authentication challenge RAND.

Yet another possibility to authorise the authentication challenge is to provide the authentication challenge RAND with a digital signature. The message comprising the random number RAND and the digital signature may be encrypted using the authentication key K_i. Again the ciphering algorithm for encryption of the message and the length of the random number RAND and the digital signature have to be adjusted such that the entire message to be transmitted from the visiting MSC/VLR has the length of the usual authentication challenge and the appearance of randomness. The SIM would be provided with means for decryption of the message and to verify the digital signature.

Moreover, it is appreciated that more than one valid key K_i and/or more than one fake key K_i' (i.e. K_i'', K_i'''...) can be stored on the SIM card and can be used to calculate the response for invalid authentication challenges. The different valid keys K_i or fake keys K_i', K_i'', etc may, for example, be used alternately if a valid or invalid authentication challenge is detected. Alternatively, one valid or fake key may be selected according to a predetermined selection procedure which may, for example, be based on the

random number RAND, the certificate CERT or an external variable parameter.

It if further appreciated that only one authentication key K_i is used, but more than one authentication algorithms A_3, A_3', A_3'', ... rather than more than one authentication key K_i are used in the authentication method described.

Whilst in the above-described embodiment the SIM card responds to authentication challenges by performing the same procedure but using an invalid "fake" authentication key or algorithm, it is appreciated that the SIM card may not respond to unauthorised and thus false authentication challenges. In this case the SIM card stores data indicating that an false challenge is detected and consequently the SIM card will not respond to any further authentication challenges by transmitting an authentication response SRES. In this way the possibility of misuse of the SIM card is further reduced.

In a second embodiment of the present invention the authentication centre AuC stores a number of authentication codes Ca. In this embodiment when a subscription is started a number of authentication keys K_i are allocated to the mobile subscriber. There is one authentication key K_i assigned to each possible authentication code for each subscriber in the GSM network.

The database 32 of the authentication centre AuC is further provided with means for randomly choosing or selecting in another way one of the authentication codes. After choosing one of the authentication codes, the AuC retrieves the authentication keys K_i assigned to the chosen authentication code

and the authentication centre generates a random number RAND as an authentication challenge. The authentication response SRES is then calculated from the random number RAND and the assigned authentication key K_i fed into an authentication algorithm A_3 as described before. The AuC then sends a message comprising the random number RAND, the authentication code Ca and the authentication response SRES. The random number RAND and the authentication code Ca is sent to the visited MSC/VLR and further transmitted to the mobile station as an authentication request. Again a sequence of messages containing RAND and Ca should have the appearance of randomness in order not to alert a potential attacker. In the simplest case the authentication code might for example consist of a 1 bit message with is stored in a predetermined place within a 127 bit random number RAND, such that the message comprising RAND and Ca is the common 128 bit format for authentication challenges according to the GSM standard. In case that Ca is 0 or 1, there is assigned a first authentication key K_i or a second key K_i', respectively, for use in calculating the authentication response SRES.

The SIM card is also provided with the authentication codes, keys and their predetermined assignments as illustrated in Figure 7. The SIM card is provided with information identifying which region of the received authentication request the authentication code Ca is stored. On reception of an authentication challenge from the visited MSC/VLR the SIM card reads

the Ca and retrieves the authentication key K_i assigned to the received authentication code Ca from its memory and calculates an authentication response SRES from this assigned authentication key K_i and the received random number RAND. Again SRES is sent as an authentication result to the visited MSC/VLR and there compared to the SRES as received from the AuC. Access is granted if the two authentication results are identical, access is denied if they are not identical. In this way the SIM card is protected against multiple attacks, because it would not be possible to derive the authentication key K_i from challenging the SIM with random number RAND according to the GSM standard and monitoring the authentication responses SRES.

Whilst in the above described embodiment the use of authentication codes are described in response to which one authentication key is chosen, it is appreciated that alternatively a characteristic of the authentication challenge itself may be used. For example a checksum or a cyclic redundancy code may be derived from the random number RAND or portions thereof to determine which authentication key is used. Another possibility is that a portion of predetermined length and position of the authentication challenge itself, for example, the last two bits, determine which authentication key is used. It is further appreciated that one of a number of different authentication algorithms may be used rather than, or in addition, selecting one of a number of different authentication keys.

Whilst in the above-described embodiment an authentication key or algorithm assigned to a received authentication code or a characteristic derived from the authentication challenge is used to generate an authentication response, it is appreciated that alternatively an external variable input parameter may be used to select an authentication key or algorithm. An example for such an external variable parameter is for example the date or a parameter derivable from the TMSI (Temporary Mobile Subscriber Identity) according to a predetermined algorithm.

Whilst in the above-described embodiments an authentication code or characteristic derivable from the authentication challenge is used to select in a predetermined way an authentication key or algorithm, it is appreciated that either the network (i.e. the AuC) or the SIM card may select one of a number of authentication keys or algorithms and respond by generating SRES using this selected key or algorithm. In this case both the AuC and the SIM card are provided with more than one keys or algorithms. Whereas the AuC or the SIM selects one of these keys or algorithms, the according other party (i.e. the SIM card or the AuC) provides more than one authentication responses SRES. The authentication procedure is successful and thus access for the mobile station carrying the SIM is granted if the SRES generating the selected key or algorithms is amongst the number of authentication responses SRES provided by the other party.

It is appreciated that instead of using one authentication algorithm and more than one authentication key alternatively more than one authentication algorithm and one authentication key or more than one authentication algorithm and more than one authentication key may be used.

Whilst in the above-described embodiments an authentication algorithms A_3 according to the GSM standard is used to calculate the signed response SRES, it is appreciated that other authentication algorithms may be used.

Whilst in the above-described embodiments a number of the authentication processing functions on the network side are carried out in the MSC/VLR, one or more of the processing functions may be carried out elsewhere, for example in a base station.

Whilst in the above-described embodiments the method and system of authentication is for authenticating a network entity in the form of a network operator as described in the framework of the GSM standard, it is appreciated that the method and system may also be adapted in other mobile communication systems like for example PCS and for other authentication procedures like the WS and the S scheme. The method and system may also be used for authenticating network entities such as virtual network operators, service providers, etc. The method and system may also be adapted in authentication systems other than mobile communication systems.

Whilst in the above-described embodiments a SIM card is described, it is appreciated that subscriber identifying means or information storage means other than a SIM card may be used.

It is to be understood that the embodiments described above are preferred embodiments only. Namely, various features may be omitted, modified or substituted by equivalents without departing from the scope of the present invention, which is defined in the accompanying claims.

CLAIMS:

1. A method of authentication in a mobile communications network comprising:

authentication of a subscriber identifying means to a network entity; and

authentication of the network entity to the subscriber identifying means.

2. A method of authentication according to claim 1, wherein said authentication of the subscriber identifying means to the network entity includes said subscriber identifying means receiving an authentication challenge, calculating an authentication response from said authentication challenge, an authentication input parameter stored on said subscriber identifying means and an authentication algorithm, and transmitting said authentication response to the network.

3. A method of authentication according to claim 1 or 2, wherein said authentication of the network to the subscriber identifying means includes adding a certificate to an authentication challenge for said authentication of the subscriber identifying means to the network entity.

4. A method of authentication according to claim 3, wherein said certificate includes at least one of the following:

i) a digital signature;

ii) a message authentication code (MAC); and

iii) a redundancy check code.

5. A method of authentication according to claim 3 or 4, wherein a response to said authentication challenge is given by the subscriber identifying means to a request with valid and invalid certificates.

6. A method of authentication according to claims 3, 4 or 5, wherein a valid response to said authentication challenge is only given to a request with a valid certificate.

7. A method of authentication according to any of claims 3 to 6, wherein the procedure of responding to said authentication challenge is the same for a valid and an invalid certificate and a first input parameter or algorithm is used for said procedure of responding to a valid certificate and at least one further input parameter or algorithm, different from said first input parameter or algorithm, is used for said procedure of responding to an invalid certificate.

8. A method of authentication according to claim 7, wherein said first and any further input parameter and algorithms are stored on said subscriber identifying means.

9. A method of authentication according to any of claims 3 to 8, further comprising storing data on said subscriber identifying means indicating that said subscriber identifying means has been subject to a request for authentication with an invalid certificate.

10. A method of authentication according to claim 3 or 4, wherein for an authentication challenge with an invalid certificate, said subscriber identifying means is prevented from responding to any further authentication challenges.

11. A method of authentication in a mobile communications network using an information storage means, said method comprising the steps of:

said information storage means receiving a message comprising an authentication challenge and determining a characteristic of said message;

performing a first procedure if said message has a first predetermined characteristic; and

performing a second procedure if said message has a different characteristic.

12. A method of authentication according to claim 11, wherein performing said first procedure includes generating an authentication response with an authentication algorithm based on said authentication challenge and an authentication input parameter.

13. A method of authentication according to claim 11 or 12, wherein performing said second procedure includes:

generating an authentication response based on said authentication challenge, and:

i) said authentication algorithm and at least one second authentication input parameter; or

ii) said authentication input parameters and at least one second authentication algorithm; and

transmitting the generated response to the network.

14. A method of authentication according to claim 11 or 12, wherein performing said second procedure includes preventing said information storage means from responding to any further authentication challenges.

15. A method of authentication using an information storage means,

said information storage means receiving a message comprising an authentication challenge and determining a characteristic of said message,

said information storage means comprising means for calculating an authentication response based on said authentication challenge, an authentication input parameter and an authentication algorithm,

said method comprising the steps of:

retrieving one authentication input parameter from a number of input parameters stored on said information storage means or one authentication algorithm from a number of algorithms stored on said information storage means in response to said characteristic; and

responding to said authentication challenge by using said retrieved authentication input parameter or algorithm.

16. A method of authentication according to any of claims 11 to 15, wherein said characteristic of said message is derivable from said authentication challenge.

17. A method of authentication according to claim 16, wherein said characteristic is determined using checksums, cyclic redundancy codes or by portions of predetermined length or predetermined position.

18. A method of authentication according to claims 11 to 15, wherein said message includes said authentication challenge and an authentication code and said characteristic of said message is included in said authentication code.

19. A method of authentication according to claim 18, comprising the step of selecting one authentication code from a number of different authentication codes, whereby each authentication code is assigned to a particular input parameter or algorithm.

20. A method of authentication according to claim 19, wherein said authentication codes, input parameters or algorithms and assignments of said codes to said input parameter or algorithms are stored on said information storage means.

21. A method of authentication according to any of claims 3 to 10 and 18, wherein a sequence of messages comprising said authentication challenges and said certificates or authentication codes have the appearance of randomness.

22. A method of authentication according to any of claims 3 to 10 and 18 for authentication in a mobile communications network, said communications network being in accordance with the GSM standard, wherein said authentication challenge comprises a message of (128-n) bits and said certificate or authentication code comprises a message of n bits, such that a

message comprising said authentication challenge and said certificate or authentication code is 128 bits long.

23. A method of authentication, comprising distinguishing an authorised request for authentication from an unauthorised request for authentication and responding differently to authorised requests than to unauthorised requests.

24. A method of authentication according to claim 23, further comprising storing data on an information storage means indicating that said information storage means has been subject to an unauthorised request for authentication.

25. A method of authentication according to claim 23 or 24, wherein said request for authentication includes an authentication challenge.

26. A method of authentication, comprising the step of using a first valid input parameter or a first authentication algorithm to respond to an authorised authentication challenge and using a second input parameter or a second algorithm, different from said first input, to respond to an unauthorised authentication challenge.

27. A method of authentication according to claim 26, further comprising storing data on an information storage means indicating that said information storage means has been subject to an unauthorised authentication challenge.

28. An authentication centre for a mobile communications network, comprising:

a database storing a secret authentication input parameter for subscribers of said mobile communications network;

a source for providing random numbers as second input parameters;

means for calculating certificates for authorising authentication challenges, including an algorithm for calculating said certificates; and

means for calculating authentication responses, including an algorithm for calculating said responses.

29. An authentication centre for a mobile communications network, comprising:

a database storing:

i) an authentication algorithm and at least two secret first input parameters; or

ii) a secret first input parameter and at least two different authentication algorithms for calculating authentication responses;

a source for providing second input parameters for calculating said authentication responses;

means for:

i) determining characteristics of said second input parameters; or

ii) providing authentication codes;

means for assigning one of said at least two secret first input parameters or authentication algorithms to said characteristics or said authentication codes in a predetermined way;

means for retrieving the assigned first input parameter or authentication algorithm from said database; and

means for calculating said authentication responses using said assigned first input parameter or authentication algorithm.

30. An information storage means for authentication, adapted for distinguishing authorised and unauthorised requests for authentication and for responding differently to said authorised and said unauthorised authentication requests.

31. An information storage means according to claim 30, wherein said authentication requests include authentication challenges and responding to said authentication challenges include calculating an authentication response

from said authentication challenge an authentication input parameter and an authentication algorithm.

32. An information storage means according to claim 31, wherein said authentication challenges carry certificates for authorising said authentication challenges.

33. An information storage means according to claim 32, wherein the validity of said certificate can be checked by calculation of said certificate from a certifying key and a certifying algorithm stored on said information storage means using said authentication challenge as an input parameter and by comparing the calculated and received certificate.

34. An information storage means according to any of claims 30 to 33, said information storage means being adapted for storing a first authentication input parameter or algorithm for use in a procedure of responding to authorised requests for authentication and further adapted for storing at least another authentication input parameter or algorithm for use in a procedure of responding to unauthorised requests.

35. An information storage means according to any of claims 30 to 34, further adapted for storing data on said information storage means indicating

that said information storage means has been subject to an unauthorised request for authentication.

36. An information storage means for authentication, comprising:

means for calculating authentication responses to received authentication challenges using said challenges, an authentication input parameter and an authentication algorithm stored on said information storage means;

means for:

i) determining characteristics of said authentication challenges; or

ii) determining characteristics of received authentication codes;

means for storing:

i) an authentication algorithm and at least two secret authentication input parameters; or

ii) a secret authentication input parameters and at least two authentication algorithms

means for determining predetermined assignments of said characteristics to said at least two authentication input parameters or algorithms; and

means for retrieving the assigned authentication input parameters or algorithms for a particular characteristic or authentication code and using said

assigned authentication input parameter or algorithm for calculating said authentication responses.

37. An information storage means according to claims 32, 33 or 36, for authentication in a mobile communications network according to a GSM standard, wherein a received message comprising said authentication challenge and said certificate or authentication code have the same appearance as an authentication challenge according to the GSM standard.

38. A subscriber identifying means for authentication in a mobile communications network, adapted for distinguishing a genuine authentication challenge as transmitted by said network from a false authentication challenge and for storing data indicating that said subscriber identifying means has been subject to false authentication challenges.

39. A method of authentication in a mobile communications network, comprising transmitting an authentication request to a mobile station and receiving an authentication response from the mobile station, wherein the authentication request transmitted to the mobile station comprises:

an authentication challenge; and

a certificate, said certificate providing authentication of a network entity to or an authentication code for determining a procedure for responding to said authentication challenge.

40. A method of authentication in a mobile communications network,

wherein a network entity transmits an authentication challenge to a subscriber identifying means and generates an authentication response to said challenge,

wherein said subscriber identifying means generates an authentication response to said received challenge and transmitting said response to said network entity,

wherein said network entity compares the authentication response generated by said network entity to the authentication response provided by said subscriber identifying means, and

wherein said method comprises the steps of generating said authentication responses using a variable external input parameter available to said network entity and said subscriber identifying means and calculating said authentication response in response thereto.

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Application No:	GB 0019110.6	**Examiner:**	Nigel Hall
Claims searched:	1, 2	**Date of search:**	16 March 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H4L (LRCMA); H4P (PDCSA)

Int Cl (Ed.7): H04Q 7/38

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2301740 A1	(DSC)	1
X	GB 2279540 A1	(KOKUSAI DENSHIN DENWA)	1
Y	EP 0915630 A2	(LUCENT) See col. 7 lines 34-39	1,2
X	WO 99/33299 A1	(SIEMENS)	1
Y	WO 98/00956 A2	(MCI) See p. 7 lines 9-16	1,2
Y	WO 96/0485 A2	(ERICSSON) See p.10 lines 22-33	1,2
X	US 5875394	(DALY)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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Application No:	GB 0019110.6	**Examiner:**	Nigel Hall
Claims searched:	3-10	**Date of search:**	24 January 2002

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4L (LRCMA); H4P (PDCSA)

Int Cl (Ed.7): H04Q 7/38; H04L 9/32

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	WO 00/72506 A1	(IBM) See claim 1	3 at least
X	WO 99/39476 A1	(CERTICOM) See p.2, lines 9-30	,,
X	EP 0998073 A2	(MATSU) See abstract	,,
X	US 5371794	(DIFFLE) See abstract	3,4,6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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Application No:	GB 0019110.6	**Examiner:**	Nigel Hall
Claims searched:	11-22, 26, 27	**Date of search:**	24 January 2002

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4L (LRCMA); H4P (PDCSA)

Int Cl (Ed.7): H04Q 7/38; H04L 9/32

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	EP 1005244 A1 (ICO) See abstract and col. 15, line 41-col.16, line 5	11

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Application No:	GB 0019110.6	**Examiner:**	Nigel Hall
Claims searched:	23-25, 30-35, 37	**Date of search:**	24 January 2002

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4L (LRCMA); H4P (PDCSA)

Int Cl (Ed.7): H04Q 7/38; H04L 9 /32

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.